THE ACTS ADAPTIVE COMPUTERIZED TRAINING SYSTEM: A KNOWLEDGE BASE SYSTEM FOR ELECTRONIC TROUBLESHOOTING

Dianne F. Boyd, Steven C. Johnston, and Cynthia Clark
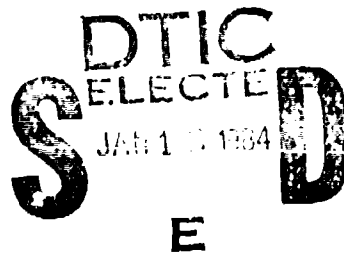Perceptronics, Inc.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the work performed during the third year of a three-year
program of research and development directed towards transferring the Adaptive
Computerized Training System (ACTS) into the training environment at Ft. Gordon
Georgia. The ACTS is a training system used to teach electronic troubleshoot-
ing procedures with particular emphasis focused on the accurate representation
of expert knowledge. Artifical Intelligence techniques are applied to the
training situation by employing knowledge acquisition features to construct
a knowledge base for simulation of electronic equipment under repair.

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ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY of THE ADAPTIVE COMPUTERIZED TRAINING SYSTEM

ES1.   The Problem Domain

The Army Research Institute sponsored research and develpoment of the "Adaptive Computerized Training System" (ACTS: contract no. MDA903-78-C-2039) to investigate methodologies for representing expert knowledge in an automated system that could provide Computer Assisted Instruction in an electronic troubleshooting environment. The targeted environment was a radio repair course at the Army Signal School - Ft.Gordon, Georgia. A sizeable training problem had evolved in the 31 Echo course due to the following conditions:

(1)   the basic aptitude of recruits had declined significantly over a five year period.

(2)   a self-pased form of classroom instruction had been implemented which increased the demands on instructors to perform more administrative duties.

(3)   a previously developed Computerized Training System did not lend itself to interactive troubleshooting.

(4)   bottlenecks occured when students waited to be evaluated while others finished training on the available equipment.

(5)   classrooms became overcrowded and instructors were barely able to keep pace with the numbers of incoming recruits.

(6)   the actual equipment for student training use was in short supply and student access to potentially dangerous high voltage components was not encouraged.

These factors and others resulted in a training approach that aimed more at training students as adequate "radio mechanics" rather than proficient

technicians. The research and development effort initiated by ARI was geared towards providing a solution to this problem through implementation of a general purpose, knowledge based, CAI system for electronic troubleshooting. A summary of the ACTS model, its principal components, the training environment and areas for theoretical improvement is presented in the following sections.

ES2. Model of the ACTS Knowledge Based System.

As the Adaptive Computerized Training System (ACTS) emerged from the laboratory to find a home in the "real-world" applications area of electronic troubleshooting, a new approach was adopted to accomplish the transition. The initial ACTS research focused on ways to model expert and student decision making behavior as capturable importance dimensions. These dimensions, or attributes, could then be processed to compute utility aggregates for attributes such as a.)the fault information to be gained by a decision, b.) the value of fault information to be gained by a decision, and c.) the value of component isolation information to be gained by a decision. This multi-attribute utility (MAU) model (Hopf-Weichel, Purcell, Freedy, Luccaccini, 1979) could represent generic circuit troubleshooting strategies and was found to be more effective than the expected utility (EU) approach used in the original ACTS. The MAU model was ideal for expert modelling since adaptive training techniques could be applied and experimental results evaluated. The ACTS MAU model in the laboratory system required the student to analyze probabilites and utility

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estimates across a set of decision options during the troubleshooting activity. Those thought processes could then be captured in the "student model" and compared to the embedded "expert model" for convergence/divergence behavior. Adaptive feedback was provided as the MAU model continuously tracked the students decision performance during the course of training.

However, when the actual training environment was examined it was determined that a new approach would be needed to place an interactive, electronic troubleshooting system into the classroom. Subject matter experts (SME's) and instructional specialists at the signal School felt that the decision-making aspects of ACTS were far too complicated for the average student in the 31E course. They had developed training techniques to cope with changing recruit capability levels, changes in classroom loading and other conditions identified above in section ES1. They desired to have a system that could accommodate changes in instructional techniques over time and additionally be able to reflect the differing approaches used by individual instructors. Hence, the artificial intelligence techniques incorporated in the ACTS MAU model were overlaid by a knowledge based system that permitted a more realistic representation of electronic troubleshooting training as it actually occurred in the classroom. The MAU model was modified to quantify the utility and probability feedback information in a score that students could more easily relate to. In addition, many automated management tools were created to assist instructors with courseware authoring, student monitoring, and instructional

ES-3

development. An Overview of the ACIS knowledge based system is illustrated in Figure E1.

In designing the ACIS for the training environment at Ft. Gordon, an exhaustive front-end-analysis was performed to acquire knowledge from the experts about electronics devices (in this case, the R1524 radio) and their training requirements. Representation of this information was refined through repeated validation cycles before final construction of the knowledge base. Once constructed, the knowledge base could then be manipulated by SME's or instructors to specify their individual approaches towards presenting electronic troubleshooting instruction. They could tailor the content specific data, i.e. the graphic display representation of circuits, symptoms associated with different problems, the forward chaining representation in the scheme composition, and the dynamic sequencing of troubleshooting problems presented to students. The flexibility of the new ACTS knowledge based system is unparalleled for electronic troubleshooting by other CAI systems such as PLATO, PLANIT, or PILUT.

ES3. Components of the ACTS Training Environment.

The development of ACTS for the Signal School integrated substantial instructor components with student training components to provide a user-friendly training
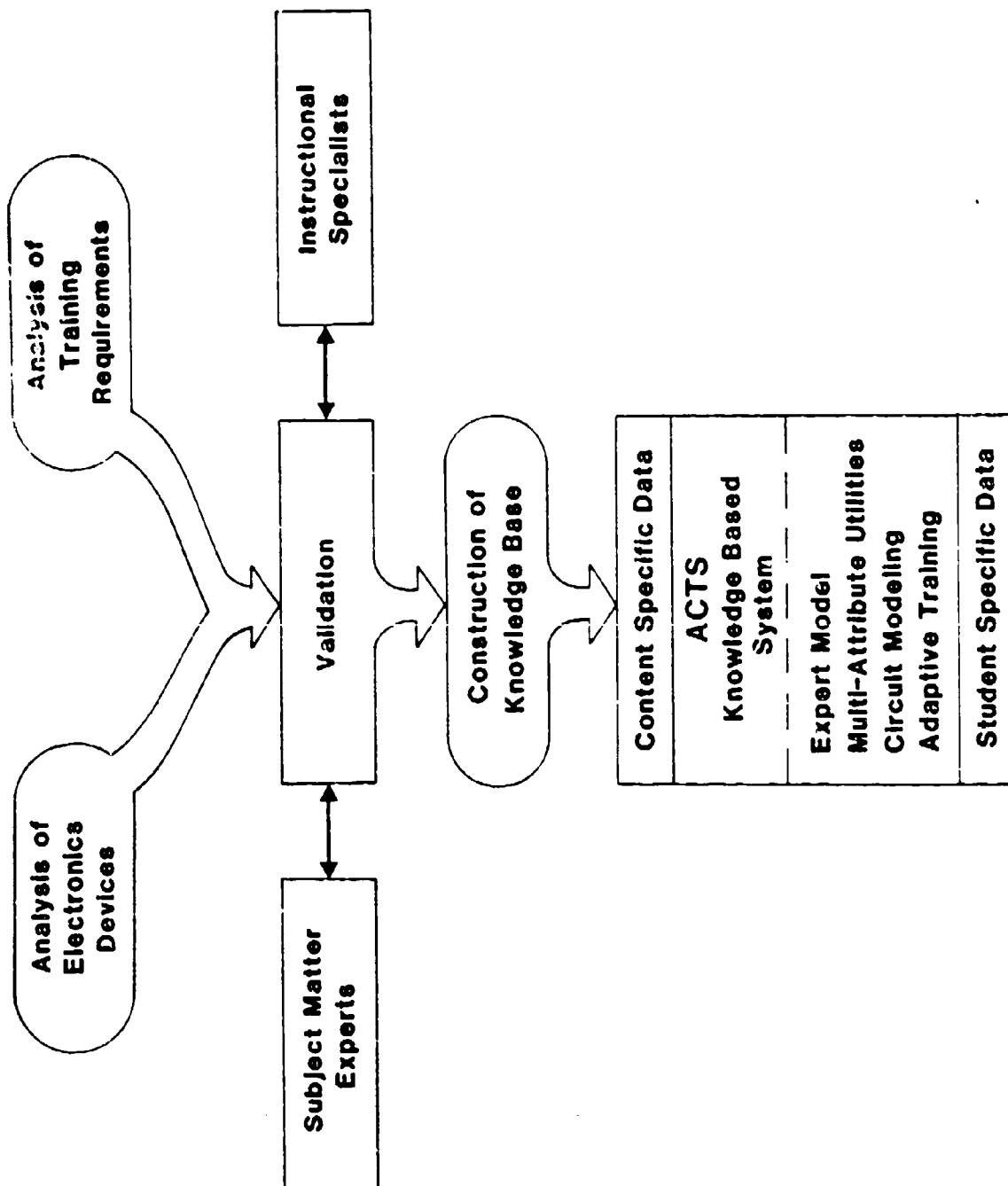
FIGURE E1 - OVERVIEW OF ACTS KNOWLEDGE BASED SYSTEM

environment. A major requirement of the project was to provide course authoring programs that would make courseware construction easy to accomplish for the SME's and instructors at the Signal School. The overall design of ACTS was geared towards development of a generic system that could be used to train electronic troubleshooting for many different types of devices. Figure E2 highlites the primary components of ACTS showing the different program modules for instructors and students. An important aspect of the ACTS is its capability to provide students with traditional computer aided instructional training, complete with testing and adaptive remedial training. This feature permits the development of a complete course of training material to be delivered to the student prior to the electronic troubleshooting component. Our focus at the signal school was to provide courseware for the transmitter section of the R1524 radio, i.e. instructional content material normally covered in one objective of the 31 Echo course, ACTS could easily provide instruction for all objectives in the 31 Echo course through further courseware development.
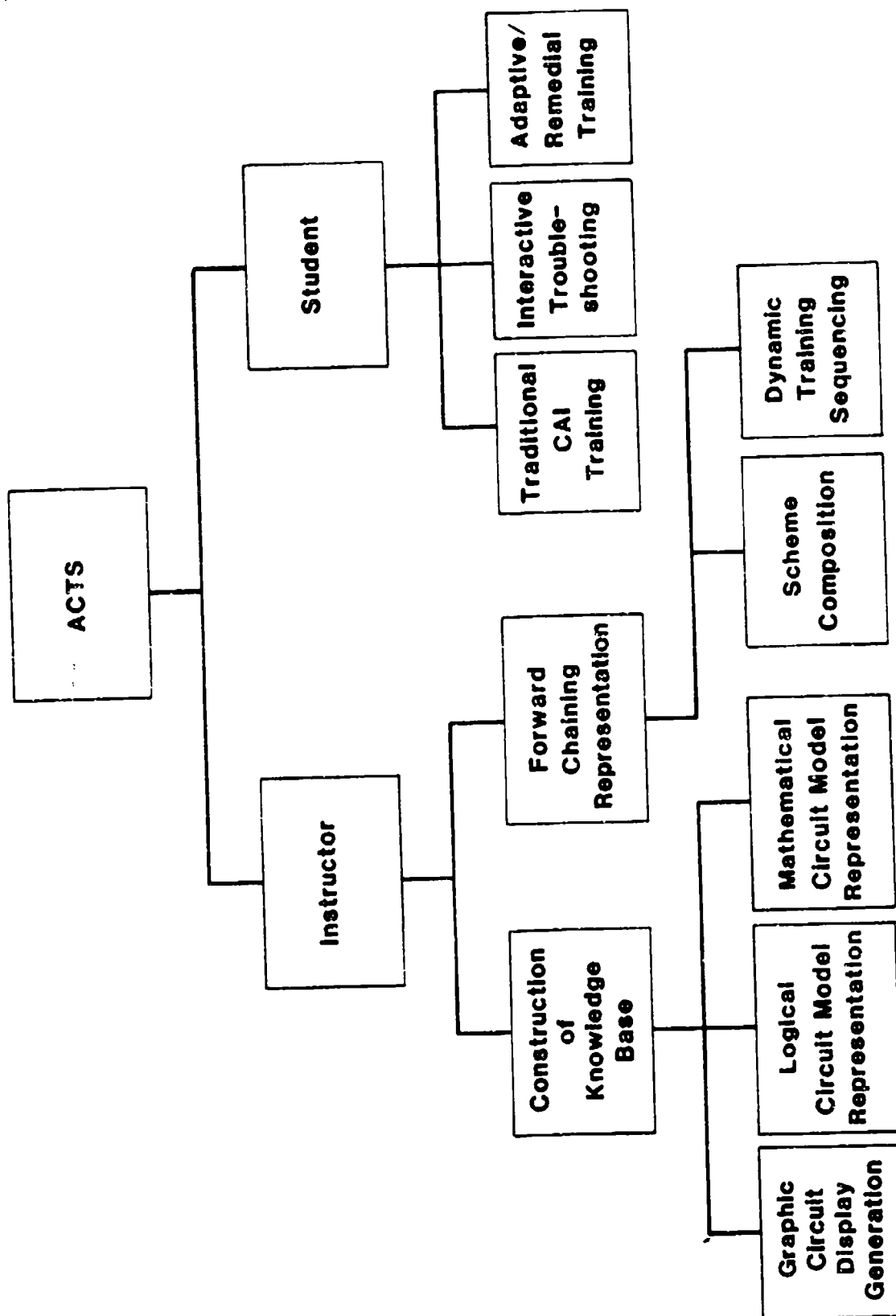
FIGURE E2 - COMPONENTS OF ACTS

ES4. <u>Acceptance</u> <u>of</u> <u>ACTS</u> <u>in</u> <u>the</u> <u>Training</u> <u>Environment</u>

In January of 1981, during the front-end-analysis phase of ACTS transfer to Ft. Gordon, the laboratory version of ACTS was installed and demonstrated at Ft. Gordon.   The training managers, instructors, and SME's who participated in those demonstrations provided feedback that helped define the requirements for the knowledge based version of ACTS.   Their responses included the following:

(1) the MACE model approach with its decision making activity was too complicated for 31E students

(2) a need was identified for actual test point measurement values to be provided during the troubleshooting process

(3) a heirarchical scheme should be implementedf that represents actual troubleshooting processes of "sectionalization", "localization", and "isolation".

(4) a set of course authoring prigrams were required that would permit instructors to design troubleshooting problems.

(5) instructor management aids would be required to perform student monitoring

(6) the courseware develoned for the 31E cooursr should be validated by SME's prior to use in the classroom.

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These six objectives guided the design and implementation of the knowlede based version of ACTS that was demonstrated at Ft. Gordon in April of 1981. The new system met with overwhelming success --- described by one SME as "...yes, it can teach". By December of 1981 the full ACIS had been installed at Ft. Gordon on their computer, complete with all course authoring programs, validated courseware, and operational with multiple student terminals. Several training sessions were held to instruct SME's in the techniques of developing new courseware and several students used ACIS on a trial basis to validate its operation prior to full classroom evaluation. One student, who had completed traditional classroom training on the R1525 transmitter, worked all of the troubleshooting problems on ACIS without any prior terminal tutorial training or use of the student manual.

The student evaluation plan had been scheduled when a series of events disrupted the continuation of the project. These included:

    (1)   schedule changes for the 31 Echo course in the Signal School

    (2)   The 31 Echo course was moved to a new location at Ft. Gordon

    (3)   continuation funding for the evaluation plan was delayed.

    (4)   loss of computer resources at Ft.Gordon to support ACTS in a daily training environment.

1. INTRODUCTION

1.1 Overview.

This report describes the work preformed during the third year of a three-year program of research and development directed at the evaluation of the Adaptive Computerized Training System (ACTS).

The ACTS is a training system used to teach electronic troubleshooting procedures with particular emphasis focused on the decision-making aspects of these procedures. Artificial intelligence techniques are applied to the training situation by simulating the electronic equipment under repair and by adaptive computer modeling of student behavior. The primary areas of concern during this three-year program were the evaluation of ACTS both in the laboratory and in the field, and the continued development and modification of the original ACTS software. Third year activities were to focus primarily on field evaluation and on the application of ACTS to the field radio repairer (31E) course at the U.S. Army Signal Center and Ft. Gordon (USASC&FG).

1.2 Objectives of Year Three.

There were three major objectives in year 3. The first was to conduct a thorough analysis of instructional methods and materials used in the 31E course

at Ft. Gordon. This included collaboration with RT524 Subject Matter Experts to complete the instructional design for the courseware used in ACTS. The second objective was to implement ACTS software (version 1.0) for student and research operation. The third was to conduct a field evaluation of the ACTS in the 31E course at Ft. Gordon, revise ACTS based on the result, and conduct comprehensive training of Data Systems Division (DSD) personnel and 31E instructors in the continued use and development of ACTS. Activities and accomplishments in support of these three objectives are described in detail in chapters 2 and 3 of the present report.

1.3 Approach.

Computer assisted instruction (CAI) has developed into an integral part of current training technology. CAI uses new concepts in the computer sciences along with artificial intelligence techniques to investigate the cognitive aspects of problem-solving and decision-making behavior. A forerunner in CAI technology is the Adaptive Computerized Training System, referred to as ACTS. In this system, individualized training is achieved utilizing adaptive techniques in a simulated electronic maintenance environment.

ACTS, as originally designed, is a system that tracks the behavior of a student and shapes it to resemble that of an expert. A major portion of the first year's effort consisted of developing an extended ACTS system to implement "multi-attribute utility" models to represent student and expert behavior in

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place of the original "expected value" models in ACTS. An additional effort during the first year of this project was to expand the system to accommodate multiple tasks and multiple students by developing multiple circuit capability, improving the ACTS' software organization and by generating instructional materials for two circuit modules (IP-28 and A-9000). That initial system was successfully implemented and tested in a laboratory environment.

During the second year the ACTS concept was redesigned, emphasizing its conversion to a higher order language for field implementation at Fort Gordon, Georgia. A user manual was developed, and the initial transfer of software and courseware to the Fort Gordon Army School began. An extensive series of laboratory studies focused on the sequencing of problem presentation, transfer of training, and optimal use of both ACTS training and training on simulated equipment, the effects of extended training, and the use of ACTS for training troubleshooting on an additional circuit model.

The third year's activities, as described in this report, concluded the implementation and installation of ACTS software at the Data Systems Division (DSD) at Ft. Gordon. Collaboration with the 31E Subject Matter Experts and DSD personnel resulted in further development, modification, and refinement of both the ACTS software and courseware to meet the requirements defined by 31E and DSD personnel. This effort resulted in the full development and validation of Version 1.0 of both software and courseware which presents the hierarchical fashion for the RT524/VRC Radio Transmitter in an Evaluations by instructional personnel resulted in further software modifications to reduce the amount of

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decision making information to be presented in a classroom environment.

1.4 Accomplishments.

The Adaptive Computerized Training System (ACTS) has been under development for a number of years. Initiated in 1974 under the sponsorship of the Army Research Institute, the project's major objective has been to develop a training system that would address general troubleshooting skills, as opposed to repair procedures for a specific piece of equipment. These skills would transfer to various equipment types and would reduce the substantial equipment support necessary for highly directive maintenance skill development. Although this goal has remained constant, ACTS has evolved through various implementations with continued focus research and development activity. The basic structure of ACTS, however, has not changed. Comprising the core of ACTS are four major components: the task model, the expert model, the student model, and the instructional model. By exercising these models, ACTS executes an adaptive instructional strategy that captures the student's decision making value structure, compares this structure to that of an expert, and then varies the instructional sequence to eliminate divergence. The culmination of developmental research over the period from 19/4 to the present has resulted in two distinct versions of ACTS. The research model of ACTS reflects the original adaptive instructional strategy. However, many of the previous design features of ACTS have been improved. These include

1. Multiple student option. Two or more
   students can use the system simultaneously.

2. Multiple circuit option. Students
   using ACTS may run simultaneously and
   independently using as many different circuits
   as have been developed.

3. Variable mode problem presentation. The
   sequence in which problems are presented
   to the student can be of random difficulty,
   graduated difficulty or specified by the instructor.

4. Hierarchical circuit models are used to
   present each problem as a sequencing process
   of sectionalization, localization, and
   isolation.

Noteworthly areas of accomplishment during the most recent year of effort include full installation of ACTS in the 31E training environment, design and implementation of extensive course authoring tools to provide Ft. Gordon instructional personnel with the capability to modify and create circuit model courseware, and training of Ft. Gordon DSU and 31E personnel in the operation of all ACTS components including course authoring.

1.5 Recommendations to Improve ACTS Performance.

Recommendation's for a fourth year's effort include the development and installation of upgraded versions of software and courseware. In addition, a Baseline Expert Model should be developed from Subject Matter Experts who use ACTS to troubleshoot all courseware problems. This would permit an extended evaluation of ACTS to be conducted based on the new courseware, software, and an Expert Model. This student evaluation could then be compared against the

traditional classroom training to analyze training and cost effectiveness of ACTS. The primary benefit of a Baseline Expert Model component would be that personalized courseware could be developed by each Expert. Hence, instrucotrs and SME's could tailor classroom training to reflect their differing instructional methods.

2. IMPLEMENTATION OF ACTS FOR FT. GORDON

2.1 Overview

This chapter describes two aspects of the implementation of ACTS for Ft. Gordon. First was the thorough analysis of instructional methods and materials used in the 31E course. This included as gaining a complete understanding of the specifications desired by 31E and DSD personnel. The second was the full implementation and evaluation of ACTS that resulted from end-user specifications.

2.2 Front End Analysis.

2.2.1 End-User Requirements. Initial meeting with DSD and 31E personnel in early 1981 identified several problem areas that required addressing before full ACTS implementation and evaluation. These areas included:

Screen Presentation - This involved the manner in which the equipment models were presented as well as the way students interacted with the syStEM.

Model Capabilities - This involved the flexibility of the fault matrices, the type of measurements present, and the complexity of the decision-making information presented to the students

Courseware Authoring - Instructional personnel at the signal school indicated the importance of providing easy-to-use course authoring tools so that SME's could develop extensive training materials for many applications.

Based on new requirements defined by DSD and 31E personnel, the following design changes were made to ACIS to provide a student version of the troubleshooting system:

1. The block module presentation was modified to facilitate component isolation down to the schematic level.

2. Screens 2 & 3 of the feedback displays were
   eliminated as was the expert choice feedback.
   Only the score information was retained.
   It was indicated by USD & 31E personnel that
   the decision making information was too complex
   and difficult for 31E students to fully understand.

In addition, ARI requested that the more complex version (renamed as the Research Version) also be modified, installed, and evaluated at Ft. Gordon.

2.2.2 <u>System Capabilities.</u> The ACTS troubleshooting system as implemented at Ft. Gordon, has the following capabilities:

1. Ease of Student Use. ACTS accessibility
   is established by the instructor providing
   students with direct entry into the trouble-
   shooting material after logging into the
   system.

2. Multi-Student-Use. The number of simultaneous
   users of ACTS is a function of the number
   of graphics display terminals and not a
   system imposed constraint. Students in-
   volved in the troubleshooting process can
   be accessing different circuits and different
   problems independently.

3. Student Monitoring. The instructor can monitor the
   progress of students while they are trouble-
   shooting. The instructor can also invoke
   a number of control conditions on a given student's
   troubleshooting session and obtain immediate data
   regarding student performance.

4. Circuit Development Aids. Separate utilities and
   tutorial programs are provided to assist in the
   development of new circuit modules in ACTS. Course
   Authoring capabilities of the CAI system will
   continue to be enhanced and extended.

5. Transportability - All ACTS program software is written in FORTRAN guided by the Program Design Language specifications. The system is intended to be highly modular and portable, but is graphics terminal, dependent rather than system dependent.

2.2.3 Target System Configuration. The U.S. Army Signal School at Ft. Gordon, Georgia originally utilized a network of 6 PDP 11/35 mini-computers in their Computerized Training System (CTS) environment. As shown in Figure 2-1, one of the PDP 11/35's can also be used as a satellite computing system. The Signal School provided computing resources on this PDP 11/35 to support the ACTS troubleshooting system. The Configuration arrangement of the 11/35 is as follows:

    (1) 128K words of main memory.
    (2) Memory management hardware.
    (3) 2 RKO5 2.5 million byte disk drives.
    (4) 16 line asynchronous serial I/O multiplexor (DH 11).
    (5) RSX11M operating system that supports DEC's FORTRAN IV.

    (6) Dialup hardware for remote terminal access.

-The PDP 11/35 central processor was not configured with either floating point processing hardware (FPP) or the extended instruction set (EIS) which implements integer multiply and divide instructions in hardware. However, FPP and EIS instructions are emulated in system software providing complete, although marginally slower, processing power. An analysis determined that FPP and EIS hardware are not required for operation of the ACIS troubleshooting sytem since access will be over slow speed communication lines from the classroom.

2-3

Large Capacity
Disk Storage

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┌─────────────┐                    ┌─────────────┐
│             │                    │   System    │   Local Disk
│  Data Base  │                    │  Controller │   Console
│ Controller  │ ◄──────────────►   │  PDP 11/35  │   Terminal
│  PDP 11/35  │                    │  128kb mem  │   Printer
│             │                    │ RSX11 op sys│   Tape Drives
└─────────────┘                    └─────────────┘   Other
       ▲ ▲ ▲ ▲                        ▲ ▲ ▲ ▲        Peripheral
                                                     Devices
       From Other                    To/From Other
       3 Display                     3 Display Controllers
       Controllers

       ┌─────────────┐
Local  │   Display   │
Disk   │ Controller  │
       │  PDP 11/35  │
       │  32kb mem   │
       └─────────────┘
          ▲
          ▼
     To 32 Displays
     and Keyboards
```

```
┌ ─ ─ ─ ─ ─ ─ ─┐
│   Display    │      Satellite
│  Controller  │ ◄──  RSX11
│  PDP 11/35   │      System
└ ─ ─ ─ ─ ─ ─ ─┘
       │
       ▼
   To Display
   Terminals
```

FIGURE 2.1 - CURRENT FT. GORDON CONFIGURATION

It is important to note that the FORTRAN compiler existing on RSX11 system is DEC's standard ANSII FORTRAN IV and not FORTRAN IV PLUS (F4P). F4P features were not utilized during (ACTS) implementation resulting in minimal software modifications when ACTS was transferred to Fort Gordon. However, in order to support the generalized CAI software system of ACTS it was necessary to upgrade FORTRAN IV to version 2.5. This was completed on the Ft. Gordon RSX system.

2.3 Overall Design.

2.3.1 Field System. The logical configuration of the ACTS training environment shown in Figure 2-2 contains three primary components: (1) Student Training, (2) Instructor Supervisory, and (3) System Development and Maintenance. Each component interacts with files in the system data base. Components include not only programs that present the instructional material but also programs to update and query performance files, system source files and maintenance files. Features of the three logical components are given in the following paragraphs.

Student Training Component. Included here are the instructional training units comprising the course materials for the students. The system automatically cycles the student through several phases based upon assignments. The operational segments are:
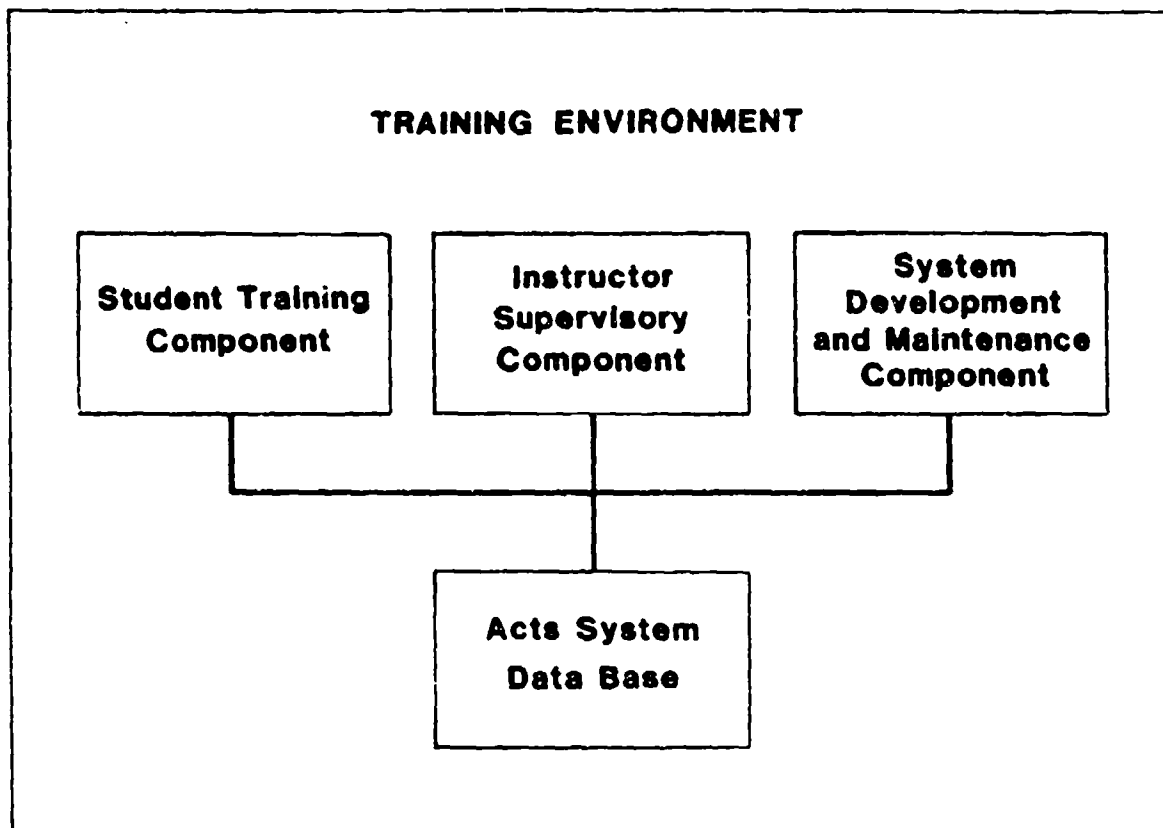

- Preliminary Instructional Objectives

FIGURE 2.2 - ACTS SYSTEM ORGANIZATION

The ACTS courseware disk is used for further development of the instructioal courseware and development of new or experimental courseware. It contains the following directories:

1. Experimental Course Authoring - contains all the ACIS course authoring tools and associated courseware directory for new or experimental development.

2. Instructional Course Authoring - Contains all of the ACTS course authoring tools and necessary courseware directories for further development of courseware curently being used.

2.4.4   Instructor System Access   - Instructors have general capabilities regarding the control and monitoring of student usage. Programs available to the instructor include the following:

1. Add student
2. Remove student
3. Review class
4. Review student
5. Modify student assignment

2.4.5   Student System Access - Students who have been given access to ACIS can only access the troubleshooting system.

2.5 Design Considerations for ACIS Enhancement

Based on requirements defined by DSD and 31E personnel, the following enhancements are recommended to improve ACIS performance and make it more

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- Graphical Troubleshooting Model
- Performance data acquisition

Instructor Supervisory Component.   These programs provide the instructor with direct control over the training environment. Functional capability of these program include:

- Student access and troubleshooting specification
- Student session monitoring
- Student performance data retrieval

System Development and Maintenance Component.   Overall system functionality and completeness are established with the addition of these operational procedures:

- Circuit module development aids
- Instructional unit installation aids
- System modeling

2.3.2 Research System.   The logical configuration of the ACTS research system is very similar to that described for the field system while providing some features not found in the field system.   These features include;

- Instructional test units for student training
- "Three-screen" ACTS

This system is installed on ARPA's DDF time-sharing PDP 11/70.   Primary utilization of the research system has been the development and preliminary testing of ACTS modifications before transfer to Ft. Gordon.

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2.4 Information Flow and Management.

2.4.1   Student Performance Recording.   Each student has a performance file constructed from an initial master record when student access is established by the instructor.   Upon completion of each training objective, the current performance record for that student is stored on his private performance file. As a student begins an interactive training session his current performance file is read into the training model, and the ACTS software invokes the correct objective or troubleshooting problem.

Each students file contains all control information necessary to specify the students current instructional status, the state of the current circuit, and generally all student and environmental control infromation needed to display or print performance information when accessed by the instructor.

2.4.2   System Operational Control.   Flow of control information in the ACTS environment is represented in Figure 2.3.   Various student and instructor activated programs update and process the three main training files. In a typical scenario the following sequence of action might occur.

    1. Instructor establishes a class of students to receive
        troubleshooting training. An activation program
        queries the instructor for student names and account
        numbers, then allows the instructor to update the
        Student Control File.

    2. Students log into the computer system and activate
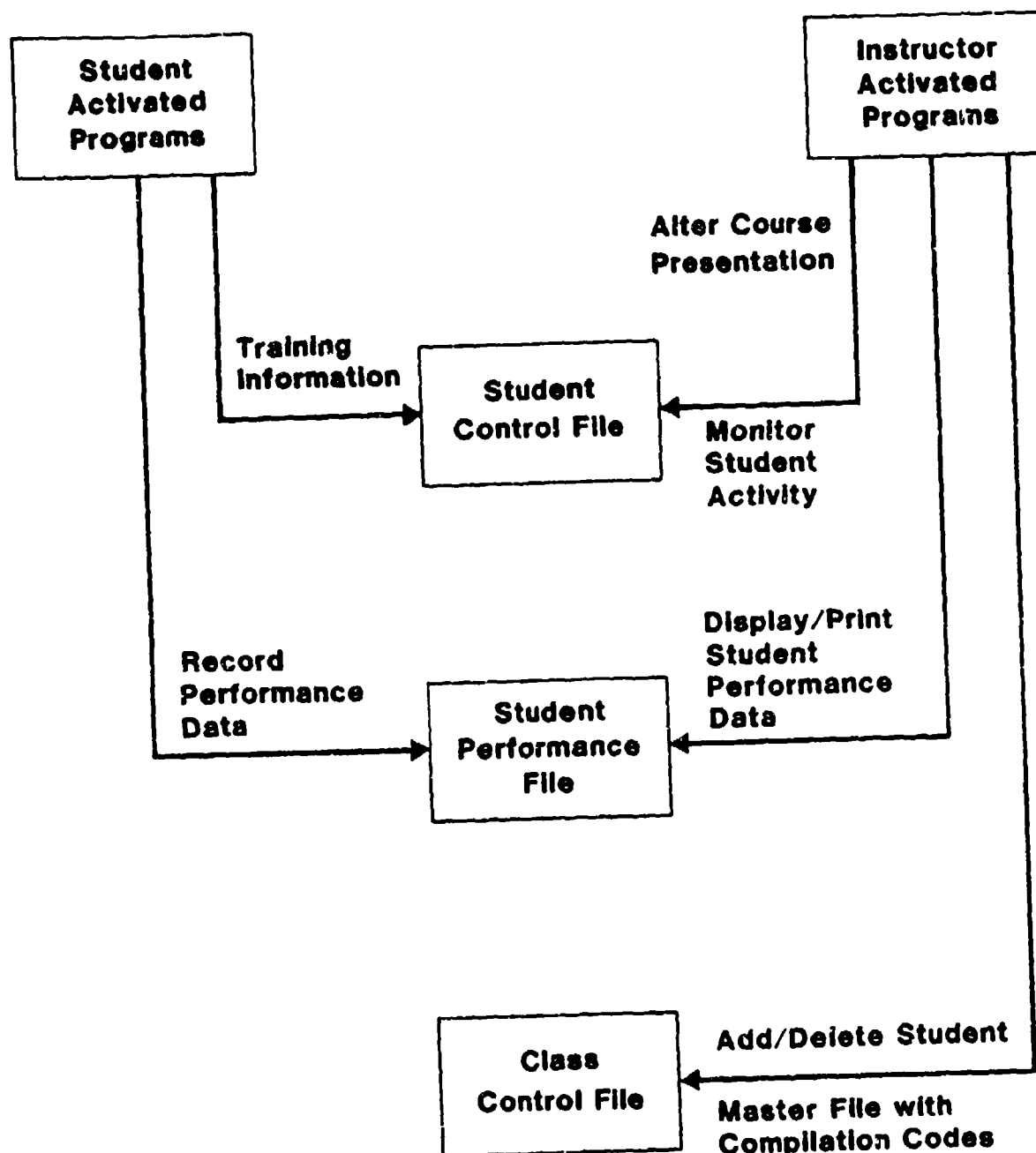
2-9

FIGURE 2.3 - LOGICAL INFORMATION FLOW

the troubleshooting program. The program loads
student's instructional and unit control information
from the Student Control File and proceeds into inter-
active troubleshooting model.

3. Instructor activates performance access program
to obtain student training results. Student
Performance File processed to display or print
information, on one or more students, requested
by instructor.

2.4.3   File System Description - This section provides a general overview of
the file organization of ACTS on the PDP 11/35 under RSX.

The ACIS system resides on four different RK05 disks. Two of these disks
contain ACIS source code and course authoring source code as well as the
necessary control files to compile, task build, and test programs. The
remaining two disks compose the operational part of the ACIS system. The ACIS
class disk is used for troubleshooting in the classroom and instructor
monitoring. It contains the following directories or accounts:

1. Instructor Directory - Provides the instructor with
access to student monitoring programs and to
ACTS troubleshooting programs.

2. Student Directories - There are 20 dif-
ferent directories that allow access to
ACTS troubleshooting and contain control
and performance files.

3. ACTS directory - contains the ACIS executable
program.

4. Courseware Directory - Contains the
Instructional Courseware for the R1524 Radio
Transmitter.

useable in the 31E environment:

1. Upgrade and expand the courseware for the R1524
    radio.

2. Upgrade ACIS software to improve multi-
    student use.

3. Consolidate and modify both the instructor
    monitoring programs and the course authoring
    tools to improve efficiency and ease of
    use.

4. Reduce the decision-making information
    presented to the student, which will
    suppress the background expert models.

5. Develop a baseline expert model from analysis
    of Subject Matter Expert decision making
    activity while utilizing ACIS troubleshooting

6. Conduct an extended evaluation of ACTS based on
    new courseware, software, and an expert model.

3. THE TRAINING ASPECTS OF ACTS

3.1 Overview

The Adaptive Computerized Training System (ACTS) focuses on improving and sharpening higher-order cognitive skills in electronic troubleshooting. Although maintenance tasks rely heavily on a technician's knowledge and training regarding the electronic systems, such tasks can be viewed primarily as decision tasks. If the technician possesses sufficient knowledge of system parts and functions, he applies it by making a series of decisions about which symptoms to look for, whether to repair or replace a malfunctioning part, and what sort of test measurements need to be made. The student's task is to troubleshoot a complex circuit by making various measurements, replacing the malfunctioning part, and making final verification measurements. Troubleshooting provides excellent application for the ACTS methodology because it is heavily dependent on judgement and probabilistic inference. In addition, troubleshooting is of great practical importance in numerous commercial and military systems, and it lends itself to economical implementation for training purposes

Work to date has produced an optional system which demonstrates the feasibility of applying artificial intelligence techniques to computer-assisted instruction in a minicomputer-based training system.

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Field evaluations by DSD and 31E instructional personnel indicated the decision models and feedback components of ACTS presented information that was too complex for feasible assimilation by the typical 31E student. This has resulted in a severe reduction in the amount of feedback information provided, essentially suppressing the background decision models.

The training given in the circuit fault diagnosis and repair task is based on the assumption that the student has a good basic backgroud in electronics but that his experience with troubleshooting is limited. This skill level can be assessed either in terms of previous training received or in terms of performance on an entering test of electronic and troubleshooting knowledge. By testing the student on the laws of electrical theory, circuit component behavior, circuit sub-systems, circuit diagrams, use of test equipment, and the like, we can determine the extent of knowledge that the student already has and then adapt the level of training to challenge him or her.

3.2 ACTS System Description

3.2.1 Task Simulator. In the ACTS, the student's decision task involves troubleshooting an electronic device. The troubleshooting task centers on a model of an electronic circuit in which faults can be simulated. Currently, the circuits modeled include all the components of the RT524 Radio Transmitter. The operation of the RT524 Radio Transmitter is simulated by the computer program, using a table-driven simulation of the fault system. The program simulates the

results of checking symptoms, taking measurements, and replacing modules.

Training in the present system occurs with certain restrictions on the extent of circuit simulation. The student interacts with a terminal which contains a display of the simulated circuit, thus he/she cannot make such troubleshooting observations as smelling faulty capactors, looking for burned resistors, or touching overheated semiconductors.

The circuit simulation was designed to meet several objectives. In additon to providing an environment for observing troubleshooting behavior, the simulator gives the results of the student's choice of alternatives by displaying the results of measurements. Finally, the circuit model is designed to simulate the essential characteristics of decision-making under uncertainty. Thus, the outcomes of the measurements are probabilistic, reflecting the fact that, in practice, fault locations are uncertain for the troubleshooter.

3.3 Instructional Approach

Training on the ACTS is provided through a system of troubleshooting units. Each troubleshooting problem consists of a hierarchical series of components leading from the top level (sectionalization) down through sub-assemblies (localization) to the schematic level (isolation.) The student can choose to take a voltage or resistance measurement, or replace any circuit module. Following a student's command to perform these activities, the ACTS program displays the results of the simulated activity. Feedback for test point measurement consists of the

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numeric value for that measurement. Feedback for module replacement consists of indicating whether the replaced module was good or faulty. Replacement of the faulty module causes transition to the next level. At the lowest level for any given problem, isolation of the faulty module or component results in a congratulatory messge and a final score.

3.4 Evaluation Plan

A summary of the extended ACTS evaluation model is presented below:

Forty students will be designated for the evaluation. All students will receive the basic electronics training course and will complete the training objectives as they normally would in the 31E curriculum. Students will then enter objective 4 and will receive circuit familiarization and the initial troubleshooting exercise. This is indicated by Steps 1 through 4 in Figure 3-1.

To supplement the student data already available, after these exercises are computed, the student will fill out a background questionnaire. A pretest will then be given on troubleshooting problems (step 5 on Figure 3-1). This pretest will be written and will consist of 10 multiple choice questions randomly chosen from a set of 20 questions. These questions will be regarding the transmitter only. The test will take approximately 1/2 hour.
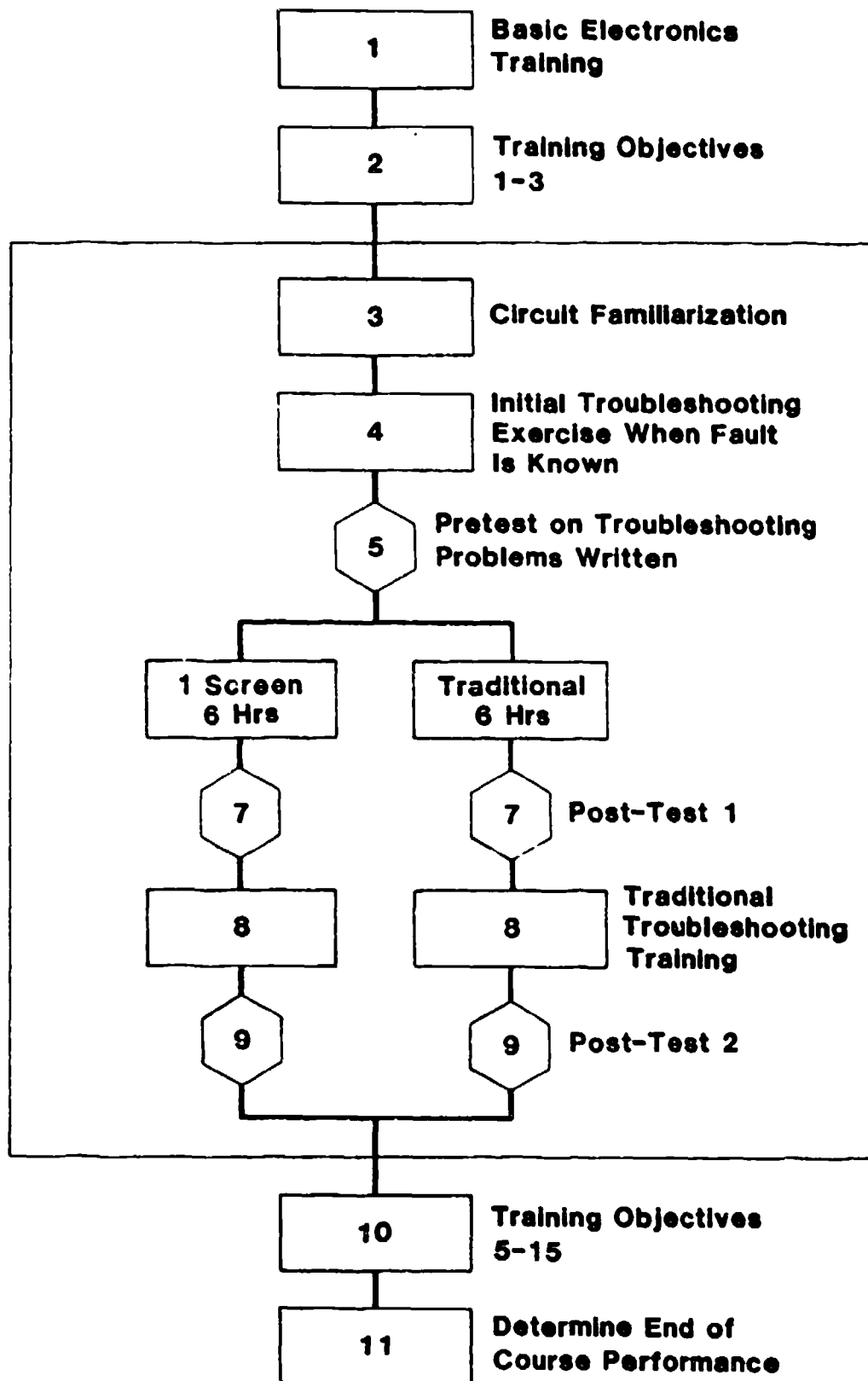
FIGURE 3.1 - ACTS-EVALUATION MODEL

After the pretest, the students will be randomly assigned to one of 2 groups, twenty students will receive the traditional troubleshooting training for a period of 6 hours. The other twenty students will receive ACIS training. They will work with the ACIS for a six-hour period, attempting to complete as many problems as possible during that time frame. The six-hour period for all students will focus on transmitter problems only. This step is indicated in the diagram as Step 6. At the completion of the 6 hours of training, all students will receive the first post-test. This will consist of 10 problems randomly generated from the 20 problems used in the pretest. This will be a multiple choice written test. It is indicated as Step 7 in the flow diagram and will take approximately 1/2 hour.

The students who received the ACTS training will then receive the traditional training. Those students who initially received the traditional trainig will continue with it. It is hypothesized that no additonal time will be required in traditional training for the students who originally received the ACTS, perhaps even less time. This will enable all of the students to complete the 4th objective in the approximate 25 hours allotted to maintain the program of training with only four to six additional hours added to incorporate the pre- and post-tests.

At the completion of the traditional training program. The students will

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receive the second post-test consisting of five problems. This test will require actual manipulation of the equipment. The students will be expected to take the appropriate number of measurements and replace the correct module in the minimum amount of time required to repair the equipment. The instructor will record the number of measurements taken, modules replaced, and the amount of time required to fix each of the 5 faults. This post-test will take approximately two hours. All groups will then go on to Step 10 which indicates traditional evaluation of objective 4 and the completion of training objectives 5 through 15.

At the end of the course, overall performance of the three groups will be evaluated by comparison of each students progression index. Complete instructions, record keeping materials and test materials will be given to the instructors to facilitate the evaluation.

APPENDIX A

Titles of Associated ACTS Reports

APPENDIX 1

The following documents, produced by Perceptronics, are associated with ACTS:

1. PIM-1076-82-01 - Instructor's Manual

2. PPRM-1076-82-01 - Programmer's Reference Manual

3. PSCDB-1076-82-01 - Summary of Current Acts Courseware Database

The following documents, produced by Perceptronics, are associated with

ACTS:

1. PIM-1076-82-01 - ACTS Adaptive Computerized Training System, Instructor's Manual.

2. PPRM-1076-82-01 -ACTS Adaptive Computerized Training System, Programmer's Reference Manual.

3. PSCDB-1076-82-01 - ACTS Adaptive Computerized Training System, Summary of Current ACTS Courseware Database

Bibliography of Reference Material

BIBLIOGRAPHY

Atkinson, R.C., October, 1972, Ingredients for a Theory of Instruction, American Psychologist, 27(10): 921-931.

Bloom, B.S., 1968, Learning for Mastery, Evaluation Comment, (UCLA Center for the Study of Evaluation), 1(2).

Brown, J.S., Burton, R.R. and Bell, A.G., March, 1974, SOPHIE: A Sophist-cated Instuctional Environment for Teaching Electronic Troubleshooting. Cambridge, MA: Bolt Beranek and Newman, Inc., Technical Report BBN No. 2790.

Carbonell, J.R., 1970, AI in CAI: An Artificial-Intelligence Approach to Computer-Assisted Instruction, IEEE Transactions on Man-Machine Systems, MMS-11(4), 190-202.

Crawford, D.G., and Ragsdale, R.G., July, 1969, Individualized Quasi-Instructional Systems for the 70's, Working paper, Ontario Institute for Studies in Education, University of Toronto.

Crooks, W.H., Kuppin, M.A., and Freedy, A., January, 1977, Application of Adaptive Decision Aiding Systems to Computer-Assisted Instruction: Adaptive Computerized Training System (ACTS), Woodland Hills, CA: Perceptronics, Inc., Technical Report PATR-1028-77-1.

Dawes, R.M., 1970 Graduate Admission: A Case Study, Oregon Research Institute, Technical Report 10 (1).

Freedy, A., and Crooks, W.H., April 7-10, 1975, Use of an Adaptive Decision Model in Computer-Assisted Training of Electronic Troubleshooting. Proceedings of the Conference on New Concepts in Maintenance Training Research, Orlando, Florida.

Goldberg, L.R., 1970, Man vs. Model of Man: A Rationale Plus Some Evidence for a Method of Improving Upon Clinical Inferences, Psychological Bulletin, 73: 422-432.

Hartley, J.R., and Sleeman, D.H., 1973, Towards More Intelligent Teaching Systems, International Journal of Man-Machine Studies, 5, 215-236.

Hopf-Weichel, R., Purcell, D., Freedy, A., Luccaccini, L., November, 1979, Adaptive Decision Aiding in Computerized Training System (ACTS), Woodland Hills, CA: Perceptronics, Inc., Technical Report PATR-1028-77-1.

Johnston, S.C., Lucaccini, L., Clark, C., and Drake, K. Adaptive Decision Aiding in Computer-Assisted Instruction: Adaptive Computerized Training System (ACTS). Perceptronics Annual Technical Report PATR-1076-80-9. (Woodland Hills, California) September 1980

Koffman, E.B., and Blount, S.E., 1974, A Modular System for Generative CAI in Machine-Language Programming, IEEE Transactions on Systems, Man and Cybernetics, SMC-4(4), 335-343.

Nilsson, N.J., 1965, Learning Machines, New York: McGraw Hill.

Samet, M.G., Weltman, G., and Davis, K.B. Application of Adaptive Models to Information Selection in C3 Systems, Perceptronics Inc. (Woodland Hills, California), Technical Report PTR-1033-76-12, December 1976.

Slagle, J.R., 1971, Artificial Intelligence: The Heuristic Programming Approach, New York: McGraw Hill.

Smallwood, R.D., 1962, A Decision Structure for Teaching Machines, Cambridge, MA: MIT Press.

Steeb, R., Chen, K., and Freedy, A. Adaptive Estimation of Information Values in Continuous Decision Making and Control of Remotely Piloted Vehicles. Perceptronics Technical Report PATR-1037-77-8. (Woodland Hills, California) August 1977.

Steeb, R., Davis, K., Alperovitch, Y., and Freedy, A. Adaptive Estimation of Information Values in Continuous Decision Making and Control of Advanced Aircraft. Perceptronics Technical Report 1037-78-12. (Woodland Hills, California) December 1978.

Van Cott, H.P. and Warrick, M.J. Man as a System Component, in Human Engineering Guide to Equipment Design, H.P. Van Cott, and R.G. Kinkade, (Eds.) U.S.G.P.O., 1972, Chapter 2.